

Age-related habitat selection by brown forest skinks (*Sphenomorphus indicus*)

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ABSTRACT

In reptiles, habitat selection is the process whereby suitable habitat is selected that optimizes physiological functions and behavioral performance. Here, we used the brown forest skink (*Sphenomorphus indicus*) as a model animal and examined whether the frequency of active individuals, environmental temperature, illumination of activity area, and habitat type vary with different age classes. We surveyed the number of active individuals and measured environmental variables at Baiyunshan Mountain in Lishui, Zhejiang, China. We found no difference in the activity frequency of adult and juvenile *S. indicus*; the activity pattern of active individuals was bimodal. The mean environmental temperature selected by adults was higher than that selected by juveniles. The environmental temperature of active areas measured at 0900-1000 h and 1100-1200h was higher than at 1400-1500h; illumination of the active area at 1000-1200h was also higher than at 1400h-1600 h. The number of active individuals, the environmental temperature and illumination of activity areas showed pairwise positive correlation. There was a difference in habitat type between juveniles and adults whereby juveniles prefer rock habitats. We predict that active *S. indicus* select optimal habitats with different environmental temperatures and types to reach the physiological needs particular to their age classes.

Keywords: *Sphenomorphus indicus*; Age-related selection difference; Habitat selection; Temperature; Illumination; Habitat type; Activity frequency

INTRODUCTION

Habitat selection is the process of animals choosing optimal habitat (Buckland et al, 2014; Johnson, 1980). Studies on habitat selection can help us understand animal behavior, population dynamics, propagation, survival and wildlife conservation (Buckland et al, 2014; Manly et al, 2002;

Strickland & McDonald, 2006). Because habitat selection variation occurs with spatial dimensional change, we can acquire information about habitat selection by examining animal distributions at specific spatial scales (De La Cruz et al, 2014; Hódar et al, 2000; Oppel et al, 2004). Studies on habitat selection have mainly focused on the three levels of population, home range and microhabitat (Thomas & Taylor, 1990). However, studies at different levels are important in determining the factors vital to habitat utilization and effective conservation measures (Beasley et al, 2007; Buckland et al, 2014; Razgour et al, 2011).

Habitat selection in most ectotherms is determined by specific thermal preferences, social interactions, predator avoidance and other factors (Angilletta et al, 2002; Dochtermann et al, 2012; Downes & Shine, 1998; Hall et al, 1992). Ectotherms are able to optimize their physiological and functional performance through habitat selection, and studies at the microhabitat level are important in understanding the mechanisms of selection. As a representative species and ectothermic group, reptiles not only need to avoid predators during activity, but more importantly, their behavior and physiological capabilities are significantly affected by temperature. It is vital that reptiles find suitable heterogeneous thermal environments to improve fitness (Angilletta et al, 2002; Castilla et al, 1999; Huey, 1982; Webb, 1996). During microhabitat selection, the activities of a reptile are under the influence of other reptiles or other species within the environment (Manicom & Schwarzkopf, 2011; Stamps & Tanaka, 1981; Wasko & Sasa, 2012). Sometimes, competition over environmental resources occurs (e.g., food, thermal resources) (Amarasekare & Coutinho, 2014;

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Marler et al, 1995; Hart & Marshall, 2012) and differences in intraspecies or interspecies habitat selection will follow.

The brown forest skink (*Sphenomorphus indicus*) is a member of the family Scincidae and mainly distributed across southern China in dark and wet grass, rock piles or cracks in cliffs (Huang, 1999). They are active away from their caves from early April to late October, and are more likely to be observed in shady areas during the morning and afternoon, and occasionally at noon. Here, we used line transects to investigate the quantity and type of habitat used by *S. indicus* in hilly road areas of Baiyunshan Mountain, Lishui, China. Environmental temperatures and illumination intensity were measured to explore characteristics and underlying mechanisms of habitat selection by *S. indicus* of different ages. Our results will aid the conservation of wild populations of this species.

MATERIALS AND METHODS

Experimental design

From May to early July 2014 we used line transect methods to investigate *S. indicus* and their habitat at Baiyunshan Mountain, Lishui, Zhejiang, China (N27°49'17.50", E120°32'14.89"). The full length of the line transect was 4 km, and the altitude at the start and end points was 140 m and 360 m, respectively. During the survey observers proceeded at an even pace along hilly road. Active individuals sighted within 2 m of the road along the cliff (width=2 m) and environmental parameters of habitat were recorded. Seventeen surveys were randomly carried out during 0900h-1230h (10 surveys) and 1230h-1600h (7 surveys) over 6 days. The weather and temperature during surveys are shown in Table 1. Active individuals were determined as adults (SVL > 65 mm) or juveniles (SVL < 65 mm) (Ji & Du, 2000) by visually estimating body size. The snout-vent length (SVL) of randomly captured individuals was measured

Table 1 Weather conditions during field surveys

Date	Time	Weather	Temperature (°C)
16/05	1230h-1600h	Sunny	22.8 (20.7-26.5)
21/05	0900h-1230h	Sunny	24.1 (17.1-31.8)
24/05	0900h-1230h	Cloudy	24.8 (20.4-31)
25/05	0900h-1230h	Sunny	26.4 (23.2-32)
27/05	0900h-1600h	Overcast to cloudy	24.1 (22.3-29.4)
01/06	0900h-1600h	Sunny	26.6 (22.7-32.3)
07/06	0900h-1600h	Overcast to cloudy	26.9 (22.0-34.3)
25/06	0900h-1600h	Overcast to sunny	25.4 (20.8-32)
06/07	0900h-1230h	Showers to cloudy	29.6 (26.0-34.0)
07/07	0900h-1600h	Showers to cloudy	26.4 (26.0-36.0)
09/07	0900h-1600h	Cloudy to sunny	29.6 (26.0-36.0)

by digital square caliper (0.01 mm, Mitutoyo, Japan) and the accuracy of visual estimation was verified. Before being released to the original capture area, the 1st toe on the left hind legs was clipped in individuals to avoid repeated sampling. Because sex can not be determined by visual estimation, gender-related differences were not considered here. The habitat of observed *S. indicus* was determined whereby grass or leaf litter layer was categorized as grass habitat and bare rock or ditch was categorized as rock habitat. An infrared radiation thermometer (UT301A, Uni-T, China) was used to measure the temperature of the spot where a skink was located, defined by a circle with a 10 cm diameter around the animal; the environmental temperature of this habitat was the average value of 10 measurements. A sensitive probe was planted at the center of this circle to measure illumination intensity (lux).

Statistical analysis

Data were analyzed using STATISTICA (v6.0). The normality and homogeneity of variance of all data were checked by Kolmogorov-Smirnov tests and Bartlett tests, respectively; no parameters required transformation before statistical analyses. The percentage of active *S. indicus* during a survey was equal to the numbers of observed active *S. indicus* during a survey divided by the total numbers of observed *S. indicus* during a survey, multiplied by 100. Contingency tables and G-tests were used to analyze age-related activity patterns and habitat type, and activity frequencies during each time period. Two-factor ANOVA was used to determine the effects of age and survey time on environmental temperature and illumination intensity of the active area. One-factor ANOVA was used to determine the effects of age-related individual differences and habitat type on environmental temperature and illumination intensity of the active area. Partial correlation was used to check correlations between numbers of active individuals during a survey period, environmental temperature and illumination intensity of the active area. Group differences were compared using Tukey's *post hoc* test. All data were expressed as mean±SE and statistical significance was taken at $\alpha=0.05$.

RESULTS

We collected 404 *S. indicus* (211 juveniles and 193 adults), and acquired parameters for habitat type, environmental temperature and illumination intensity in active areas. Body size was measured in 96 individuals (31 juveniles and 65 adults). The SVL of adults (74.7 ± 0.6 mm, 65.8-91.3 mm) was longer than that of juveniles (60.5 ± 0.7 mm, 46.0-64.7 mm) ($F_{1,94}=205.82$, $P<0.001$) and no overlap was found between the SVL ranges of adults and juveniles. The activity patterns of adults and juveniles during each survey period were comparable ($G=9.04$, $df=6$, $P=0.171$) (Figure 1A). However, when data from adults and juveniles were grouped together, differences in the proportions of active individuals during each survey period were found ($G=178.22$, $df=6$, $P<0.001$). For example, two activity peaks occurred at 1000-1200 h and 1300-1500 h, and individuals were more active during 1000-1200 h (Figure 1B).

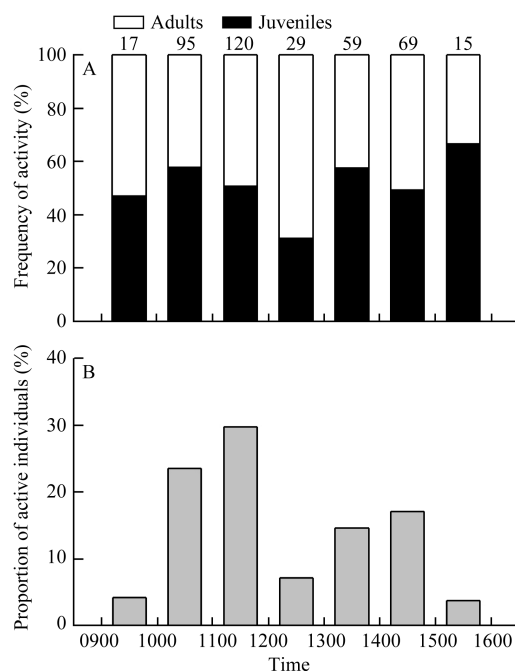


Figure 1 Activity frequency of juvenile and adult *Sphenomorphus indicus* (A) and proportion of active individuals at survey times (B)
Numbers above bars indicate sample size for each time.

Both age and survey time influenced the environmental temperature of areas of activity in *S. indicus*, but the age \times survey time interaction did not. The environmental temperature of areas of adult activity (24.8 ± 0.2 °C) was higher than for juveniles (24.1 ± 0.2 °C) (Tukey's test, $P < 0.001$). The environmental temperatures during 0900-1000 h and 1100-1200 h were both higher than during 1400-1500 h (Tukey's test, both $P < 0.03$); no differences were found across other survey periods (Tukey's test, all $P > 0.05$).

Survey time influenced illumination intensity of the areas frequented by active *S. indicus*, but age and the age \times survey time interaction did not. The illumination intensity during 1000-1200 h was higher than during 1400-1600 h (Tukey's test, all $P < 0.04$); no differences were found among other survey periods (Tukey's test, all $P > 0.05$) (Figure 2, Table 2). During each survey period, the number of active individuals, environmental temperature and illumination intensity of the active area were positively correlated (all $P < 0.04$).

Table 2 Statistical results of environmental temperature and illumination in areas where *Sphenomorphus indicus* are active

	Environmental temperature			Illumination intensity		
	F	df	P	F	df	P
Age	3.88	1, 390	<0.001	1.10	1, 390	0.295
Measurement time	8.00	6, 390	<0.01	4.58	6, 390	<0.001
Interaction	0.92	6, 390	0.480	0.97	6, 390	0.448

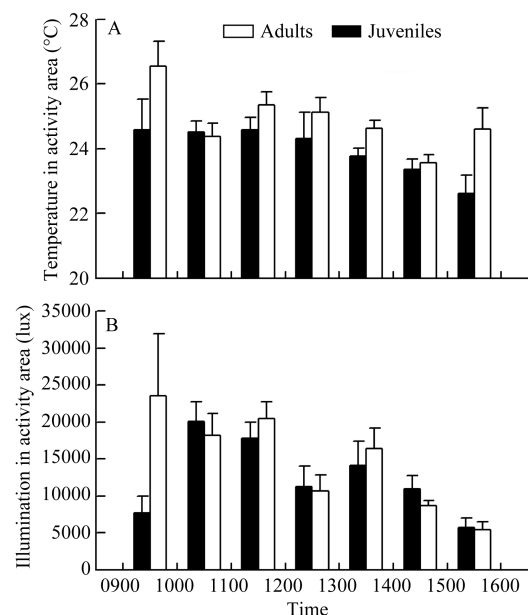


Figure 2 Environmental temperature (A) and illumination intensity (B) of areas where *Sphenomorphus indicus* are active over different survey times

Habitat type in the activity areas did not affect either environmental temperature ($F_{1,402}=0.05$, $P=0.829$) or illumination intensity ($F_{1,402}=2.49$, $P=0.115$). Habitat selection between adults and juveniles was different ($G=4.70$, $df=1$, $P < 0.04$) (Figure 3).

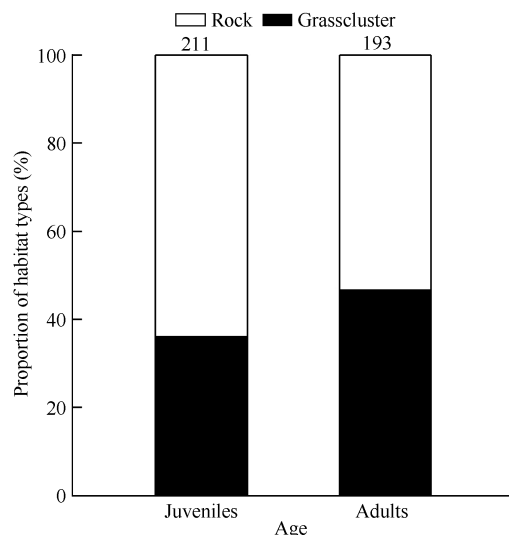


Figure 3 Proportion of habitat types selected by active juvenile and adult *Sphenomorphus indicus*

DISCUSSION

The activity patterns of reptiles is affected by many biotic and

abiotic factors (Cloudsley-Thompson, 1961; Oishi et al, 2004), including age-related energy requirements among different individuals (Liu et al, 2008; Mautz & Nagy, 1987; Oishi et al, 2004; Paulissen, 1987;). For example, the daily activity of common lizard (*Lacerta vivipara*) in juveniles is started later and shorter than in adults (Liu et al, 2008). Here, activity patterns were similar between adult and juvenile *S. indicus* (Figure 1A), indicating that because the habitat of *S. indicus* is relatively shady, wet and closed with high food abundance, skinks are less likely to compete with each other over food. It appears that niche separation over activity time distribution is not induced among individuals of different ages in this species and this is consistent with other studies on diurnal activity rhythms in other diurnal lizards (Liang et al, 2006; Liu et al, 2008; Wen & Zou, 2002;). Activity rhythms with double peaks were found in *S. indicus* during summer. The highest percentage of active individuals occurred during 1000-1200 h, and this decreased during 1200-1300 h and increased again during 1300-1500 h (Figure 1B). Differences between our results and those reported by Wang (1964) on *S. indicus* in Hangzhou are probably the result of local weather and geographic conditions.

As typical ectotherms, the biological function and behavioral performance of reptiles are significantly influenced by the thermal environment (Angilletta et al, 2002; Angilletta, 2009; Shu et al, 2010; Vermunt et al, 2014). Extreme temperatures can be harmful to individuals and good fitness requires a suitable temperature range (Clusella-Trullas & Chown, 2014; Shen et al, 2013). We found that the mean environmental temperature of the active areas frequented by adult *S. indicus* was 0.7 °C higher than the areas used by juveniles (Figure 2); a similar phenomenon has been observed in other thermal biology studies on the Iberian wall lizard (*Podarcis hispanica atrata*), the Mongolia racerunner (*Eremias argus*) and the multi-ocellated racerunner (*Eremias multiocellata*) (Castilla & Bauwens, 1991; Tang et al, 2013; Xu & Ji, 2006). These age-related differences in body temperature and environmental temperature of habitat may be correlated with body size because a small body size is usually characterized by higher thermo-conductivity but weaker heat storage capacity (Castilla & Bauwens, 1991; Tang et al, 2013; Xu & Ji, 2006). Moreover, the differences in feeding activity and predator avoidance during development may induce variation in thermal environments (Christian & Bedford, 1995; Hertz et al., 1993). The similar illumination intensities among habitats of individuals at different ages (Figure 2) indicate that illumination intensity does not affect habitat selection. However, temporal rhythms were found in both adult and juvenile *S. indicus*, i.e., the environmental temperature and illumination intensity of the active areas were both higher in mornings (0900-1200 h) than afternoons (1400-1600 h) (Figure 2), indicating that the rhythms of *S. indicus* choosing environmental factors are consistent with diurnal activity patterns. Positive correlations among the number of active individuals, environmental temperature and illumination intensity also indicate that the activity rhythms of *S. indicus* are interwoven with environmental thermal and illuminative factors.

Reptiles choose optimal habitats to obtain more thermal resources and a better chance of obtaining food (Wang, 1964; Strickland & McDonald, 2006; Buckland et al, 2014). Our study found that juvenile *S. indicus* preferred rock habitats (64%) during diurnal activity (Figure 3), consistent with Wang (1964). However, neither the environmental temperature nor illumination intensity differed between rock habitat and grass habitat, suggesting that the reason juveniles choose rock habitat is not based on acquiring more heat and illumination. The optimal physiological function and behavioral performance of lizards changes during development (Tang et al, 2013; Xu & Ji, 2006), therefore, lizards at different ages should choose different habitats to meet their physiological requirements and avoid predators (Irschick et al, 2000). For example, two species of anole lizards (*Anolis lineatopus* and *Anolis gundlachi*) in India choose habitats located in low and narrow areas to avoid predators (Irschick et al, 2000). Because the dark brown body color of *S. indicus* (Huang, 1999) is close to the color of rocks, we assume that juveniles prefer moving on rocks so as to avoid predators. We therefore predict that active *S. indicus* select optimal habitats with different environmental temperatures and types to reach the physiological needs particular to their age classes.

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